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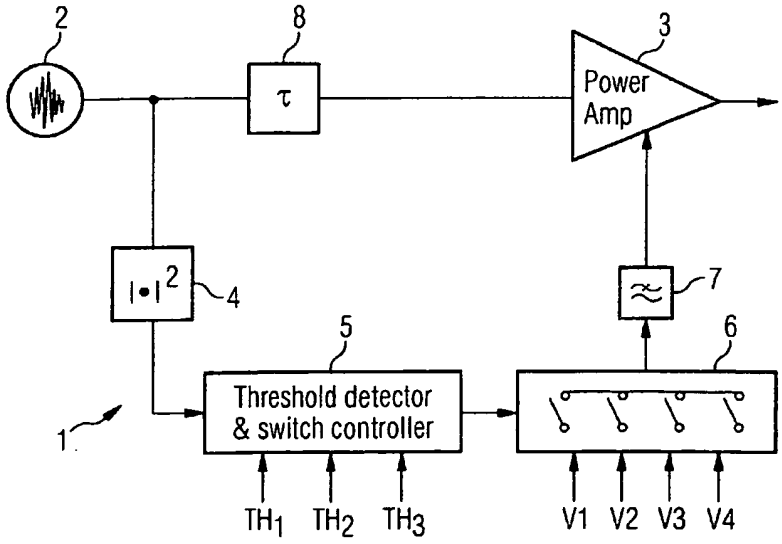
(54) Title: A POWER AMPLIFIER SYSTEM



(57) Abstract: A power amplifier system (1) comprises a control circuit; a power amplifier (3) and a delay device (8). The control circuit comprises a detector (4) for detecting an instantaneous power level of an input signal; a threshold comparator (5); and a power supply voltage source (6). The threshold comparator is provided with a plurality of preset thresholds (TH_1, TH_2, TH_3); wherein the threshold comparator compares the detected power level with the preset thresholds; wherein the power supply voltage (V_1, V_2, V_3 and V_4) is switched according to the output of the threshold comparator; and wherein the delay device (8) delays the input signal to the power amplifier to enable the power supply voltage to be adapted to the detected power level, such that the efficiency of the power amplifier (3) is optimised.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A POWER AMPLIFIER SYSTEM

This invention relates to a linear power amplifier system, in particular for use with 3rd generation mobile communication systems.

Power amplifiers can be generally categorised into three modes of operation, class A, B and C. For a linear amplifier a class A or class B amplifier amplifies a sinusoidal signal, so maximum efficiency is achieved if the output is a sinewave extending over the full range of voltage and minimum efficiency is achieved if the sinewave amplitude is minimum. Class B amplifiers are biased at zero, so the output produces current pulses with half the cycle missing which is reconstituted by subsequent filtering. Class C amplifiers are negatively biased and non-linear, in this case a low signal level also leads to low efficiency.

Mobile communications systems have in the past used constant amplitude radio waves, so it was possible to adapt the amplifier design for maximum efficiency given that the signal amplitude was known. However, 2nd generation multi-carrier operation and 3rd generation mobile communication require linear power amplifiers to operate with amplitude-variant radio frequency (RF) signals. Therefore, the power amplifier, designed to be able to deliver the maximum peak envelope power, is usually fed with a constant voltage power supply that is dimensioned to deliver the peak power and so is highly inefficient because the instantaneous envelope power is well below the peak power most of the time. Thus, the amplifier unnecessarily dissipates excess power due to the large constant power supply voltage.

Several different methods have been cited to improve the efficiency of linear power amplifiers. One method is based on the envelope elimination and restoration (EER) technique. This method has severe bandwidth limitation and therefore is not suitable for the amplification of the broadband signals used in the current mobile communication systems.

Another method is based on the principle of the Doherty amplifier. Both the EER and the Doherty amplifiers suffer from spectral spreading effects and bandwidth limitation and so are not used in current communication systems.

US2002/0084844 describes a system in which first and second amplifier stages are provided, such that if a signal power level is below a predetermined threshold, the signal is directed to a first stage amplifier to amplify the input signal and if the level is

above the threshold the signal is directed to the second stage amplifier. This system is somewhat limited in its application since it views the input signal as being simply low power or high power. Furthermore, it is inefficient in hardware terms because of the requirement to construct two amplifier stages, although only one will ever be used at any time.

In accordance with a first aspect of the present invention, a power amplifier system comprises a control circuit; a power amplifier and a delay circuit; wherein the control circuit comprises a detector for detecting an instantaneous power level of an input signal; a threshold comparator; and a power supply voltage source; wherein the threshold comparator is provided with a plurality of preset thresholds; wherein the threshold comparator compares the detected power level with the preset thresholds; wherein the power supply voltage is switched according to the output of the threshold comparator; and wherein the delay device delays the input signal to the power amplifier to enable the power supply voltage to be adapted to the detected power level, such that the efficiency of the power amplifier is optimised.

The present invention provides an efficient linear power amplifier in which the power supply voltage to the amplifier is changed according to the threshold reached by the detected input signal power level. Multiple thresholds are preset and associated with a suitable power supply voltage. This is a flexible system which provides a significant improvement in efficiency over conventional systems.

Preferably, the power supply voltage source comprises a plurality of preset power supply voltages associated with respective power level thresholds.

The system may be operated with two preset thresholds, but preferably, at least three preset thresholds are provided.

Preferably, at least four preset power supply voltages are provided.

Preferably, the system further comprises a pulse shaping filter.

Preferably, the power amplifier is a Class B amplifier and a filter is provided at the output of the amplifier to reconstitute the amplified input signal.

In accordance with a second aspect of the present invention, a code division multiple access (CDMA) communication system comprises a power amplifier according to the first aspect.

CDMA systems use radio waves which have varying amplitudes, but the present invention is able to cope with this whilst maintaining efficiency of the amplifier by switching the power supply voltage according to the input signal power level.

In accordance with a third aspect of the present invention, a method of operating a power amplifier system comprises detecting an instantaneous power level of an input signal; comparing the detected power level with a plurality of preset thresholds; switching a power supply voltage according to the output of the comparison; and delaying the input signal to the power amplifier to enable the power supply voltage to be adapted to the detected power level, such that the efficiency of the power amplifier is optimised.

Preferably, a plurality of power supply voltage levels associated with respective power level thresholds are preset.

An example of a power amplifier system in accordance with the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is an example of a power supply system according to the present invention;

Figure 2 illustrates variation in input power for an input signal using the system of Fig. 1; and

Figure 3 illustrates the corresponding variation in power supply voltage for the power amplifier of the system of Fig. 1.

Figure 1 shows one example of a power amplifier system 1 according to the present invention. An amplitude variant source signal 2, containing information that is to be transmitted, is input to the system. The signal follows a first path to a power amplifier 3 via a control circuit. The control circuit comprises an envelope detector 4, which provides a value that is proportional to the instantaneous power of the input signal 2. This value is applied to a threshold detector 5 which has N, in this case 3, preset thresholds, although more can be set if appropriate. An output of the threshold detector 5 controls switching of a switch unit 6 between N+1, in this case 4, discrete power supply voltages for the power amplifier. The chosen voltage then passes through a pulse shaping filter 7 to the power amplifier 3. The signal follows a second path to the power amplifier via a time delay 8, so that the power supply voltage of the

power amplifier is set to the correct value before the signal to which it relates is amplified in the power amplifier 3.

In operation, the threshold detector 5 compares pre-set threshold values TH_1, TH_2, and TH_3 with the value representing the instantaneous power provided by the envelope detector 4. The output of this comparison provides a control signal to turn the appropriate switch on in the switch unit 6. In this example, if the instantaneous envelope of the signal 2 is below threshold TH_1, then a voltage V_1 is applied to the power amplifier 3. If the envelope is between thresholds TH_1 and TH_2, then a voltage V_2 is applied to the power amplifier; if the envelope is between thresholds TH_2 and TH_3, then a voltage V_3 is applied to the power amplifier and finally, for all envelope values above the pre-set threshold TH_3, a voltage, V_4 is selected by the switch unit 6.

It should be noted that the invention is not restricted to three discrete threshold values, and in fact any number may be used. The number of pre-set threshold values and the corresponding supply voltages are determined to match the properties of the transmitted signal and the characteristics of the power amplifier.

A further feature of the present invention is the provision of the pulse-shaping filter 7. This filter limits the slew rate of the power supply voltage as the DC voltage is switched between the discrete values. This in turn minimizes the undesirable spectral spreading of the transmitted signal that may be caused by the power amplifier as the supply voltage is varied.

The purpose of the time delay 8 in the second path is to match the overall delay in the first path containing the envelope detector 4, the threshold detector 5, the switch unit 6 and the pulse-shaping filter 7 with the delay of the power amplifier. This ensures that the signal and the appropriate power supply voltage are applied synchronously at the correct instant.

Fig. 2a illustrates an example of how the instantaneous power determined in the envelope detector 4 varies for a particular input signal. The graph shows normalised power against time and three thresholds TH_1, TH_2 and TH_3 for the normalised power are set, at values of 0.9, 0.5 and 0.2 respectively. From Fig. 2b it is possible to see how the power supply voltage changes with each threshold transition. A normalised DC voltage is shown against time. It takes a finite period of time to reach the new value, hence the need to delay the signal into the power amplifier, so that the power supply voltage is correct.

The time delay 8, envelope detector 4 and threshold detector 5 may be implemented digitally in the baseband section of a transmitter or alternatively these elements may be realized by analog circuitry. The efficiency improvement described herein is applicable in conjunction with both feed forward and pre-distortion linearisation techniques.

CLAIMS

1. A power amplifier system, the system comprising a control circuit; a power amplifier and a delay circuit; wherein the control circuit comprises a detector for detecting an instantaneous power level of an input signal; a threshold comparator; and a power supply voltage source; wherein the threshold comparator is provided with a plurality of preset thresholds; wherein the threshold comparator compares the detected power level with the preset thresholds; wherein the power supply voltage is switched according to the output of the threshold comparator; and wherein the delay device delays the input signal to the power amplifier to enable the power supply voltage to be adapted to the detected power level, such that the efficiency of the power amplifier is optimised.

2. A power amplifier system according to claim 1, wherein at least three preset thresholds are provided.

3. A power amplifier system according to claim 1 or claim 2, wherein the power supply voltage source comprises a plurality of preset power supply voltages associated with respective power level thresholds.

4. A power amplifier system according to claim 3, wherein at least four preset power supply voltages are provided.

5. A power amplifier system according to any preceding claim, wherein the system further comprises a pulse shaping filter.

6. A power amplifier system according to any preceding claim, wherein the power amplifier is a Class B amplifier and wherein a filter is provided at the output of the amplifier to reconstitute the amplified input signal.

7. A CDMA communication system comprising a power amplifier according to any preceding claim.

8. A method of operating a power amplifier system, the method comprising detecting an instantaneous power level of an input signal; comparing the detected power level with a plurality of preset thresholds; switching a power supply voltage according to the output of the threshold comparator; and delaying the input signal to the power amplifier to enable the power supply voltage to be adapted to the detected power level, such that the efficiency of the power amplifier is optimised.

9. A method according to claim 8, wherein a plurality of power supply voltage levels associated with respective power level thresholds are preset.

FIG 1

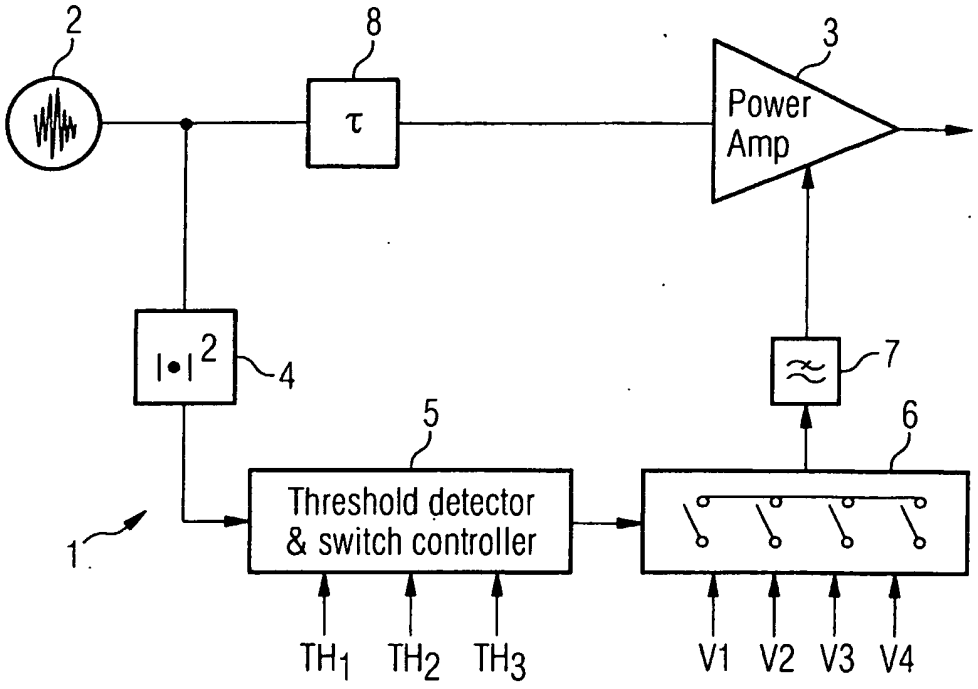

2
8
3
τ
Power
Amp
|•|2
4
7
5
6
Threshold detector
& switch controller
1
TH1
TH2
TH3
V1
V2
V3
V4

FIG 2A

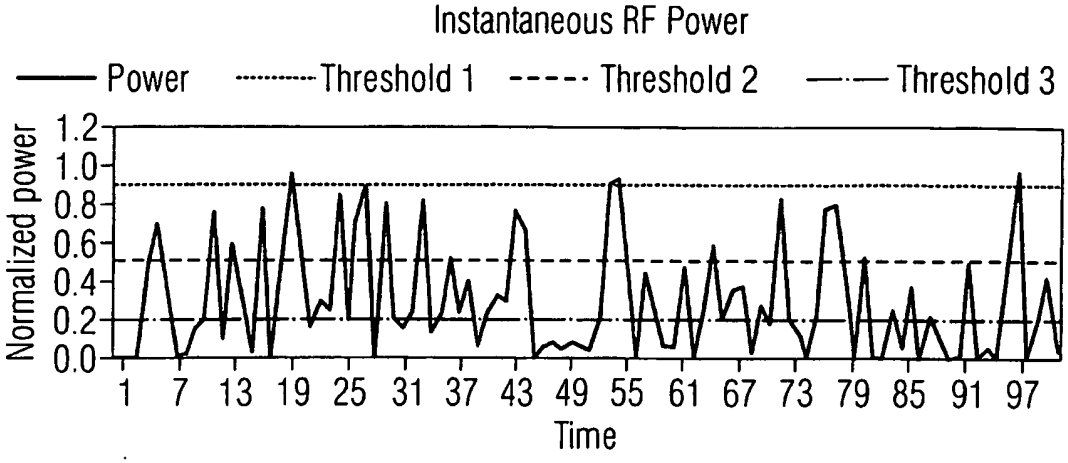
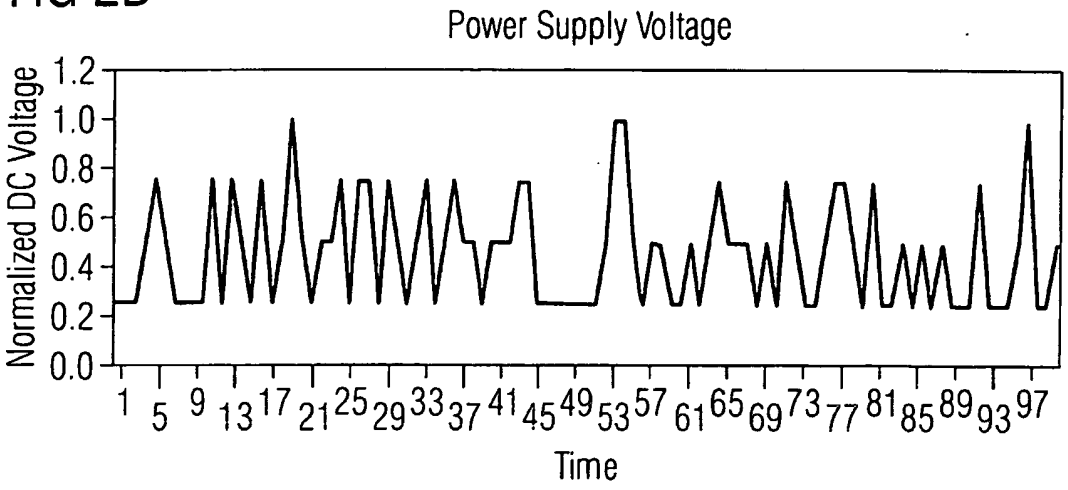

Instantaneous RF Power
Power
Threshold 1
Threshold 2
Threshold 3
Normalized power
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
Time

FIG 2B


Power Supply Voltage
Normalized DC Voltage
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97
Time

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H03F1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 0060, no. 60 (E-102), 17 April 1982 (1982-04-17) & JP 57 002107 A (PIONEER ELECTRONIC CORP), 7 January 1982 (1982-01-07) abstract	1-4,6,8,9
X	US 6 028 486 A (ANDRE TORE) 22 February 2000 (2000-02-22) abstract; figures 9,10	1,3,8,9
Y		2,4
Y	US 2001/0004387 A1 (BARKAROE STEFAN) 21 June 2001 (2001-06-21) claim 3; figure 2	2,4
P,X	WO 02 089320 A (KO BUM-JONG) 7 November 2002 (2002-11-07) the whole document	1-4,8,9

☐ Further documents are listed in the continuation of box C. ☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 November 2003	02/12/2003

Name and mailing address of the ISA	Authorized officer
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1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

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